Carbon Dioxide Blast/Vacuum Demilitarization

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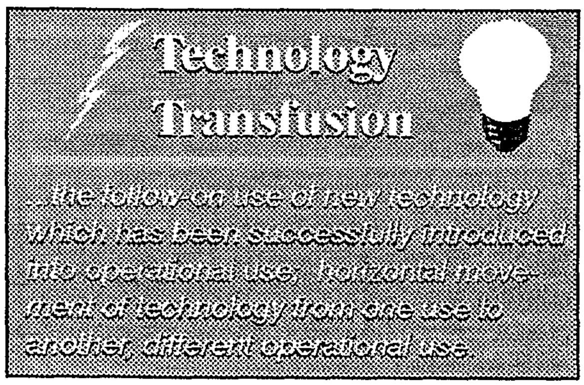
ABSTRACT: Carbon Dioxide Blast/Vacuum Demilitarization is an initiative intended to provide a new alternative to open-burning and open-detonation as a means of disposing of unwanted munitions. This initiative uses a commercially available Carbon Dioxide Blast Cleaning System which has been successfully adapted for use as a Demilitarization System by Crane Army Ammunition Activity, Crane Indiana. It is the first known use of CO_2 Blast Cleaning for demilitarization of live explosives. This initiative shows exceptional promise for reducing environmental risk while providing a cost effective disposal mechanism.

BACKGROUND: Many systems and products that have been in use for years are presenting ammunition managers with serious environmental problems when the time for disposal comes. Military ammunition and explosives comprise one of the more hazardous disposal problems in the Department of Defense.

Historically, planning for disposal of these items has been inadequate. They are consumables; they are gone once you've used them, so the alternatives to open-burning and open-detonation did not get the attention they do today. Over the past 30 years, only a handful of options for disposal of unused ammunition have been developed. The most widely used alternatives are incineration, steamout and high-pressure water washout. These methods do not come close to solving all of our disposal problems.



Now that we are really getting serious about environmental problems, the military is really getting serious about environmentally sound disposal methods. Some of these methods are being developed as brand new technology, others are resulting from adaptations of existing technology, which is known as Technology Transfusion.

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CO_2 Blast/Vacuum Demilitarization

A Technology Transfusion Initiative of Crane Army Ammunition Activity

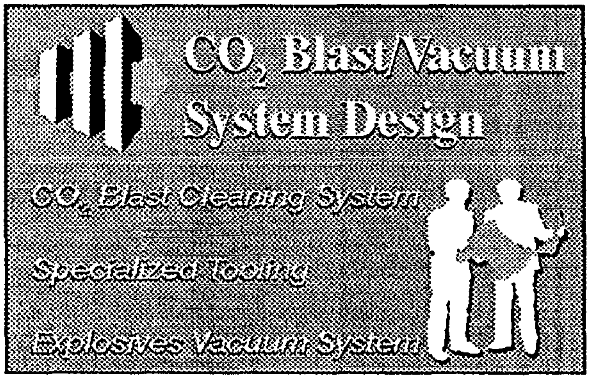
CONCEPT OVERVIEW: This concept mates a powerful vacuum with a CO_2 Blasting System, which is a sandblaster that uses dry ice pellets instead of sand. The blasting action of a CO_2 system turns the explosive filler of a projectile into powder, which can be collected in the vacuum. The pellet blaster and vacuum are mated together with special tooling that forms a closed system with a projectile. A working CO_2 Blast/Vacuum system has been successfully tested on explosive loaded projectiles. Work is underway on design enhancements to improve production efficiency.

The CO_2 Blast/Vacuum method offers substantial advantages over existing demilitarization methods. It is much simpler and requires less manpower than other systems. It doesn't require the costly water treatment plants that water based technologies do. The energy requirements are very low. The metal case can be reloaded with a new filler or turned-in for scrap without any additional cleaning. No other waste products are created, so the disposal problem is limited to the explosive itself, which in some cases can probably be sold. It may turn out to be the first economical alternative to disposal by detonation for some kinds of munitions.

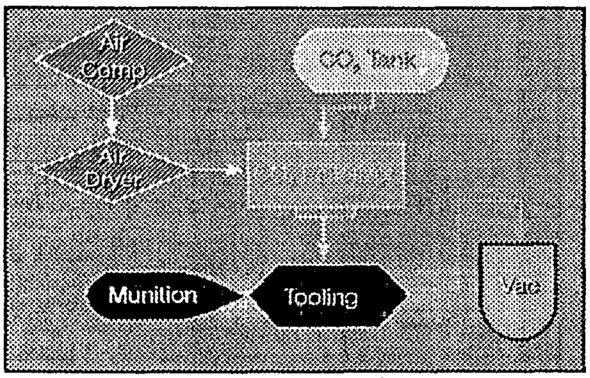
This initiative is still in the development phase, but only needs a few refinements to make it ready for a major production run. We have run a preliminary test of such a system on both inert materials and Explosive D. The prototype test used Navy 5"/54 projectiles. Inert items were used to ensure the system worked properly, then we tried it on Explosive D filled projectiles. Future testing of CO_2 Blast/Vacuum Demilitarization will be expanded to include other projectiles and explosives.

Hazards do exist. CO_2 blasting can produce powerful charges of static electricity. We control static charges by grounding the system throughout, and we included a built-in safety link that shuts the blaster off if electrical continuity is lost. In addition, we tested the system for static charges while the equipment was removing an inert filler. Our grounding system has proved adequate so far, but we will continue to watch closely for any indication of a static hazard.

CAAA is now in the process of analyzing the initial test data and redesigning the tooling for better efficiency. When that effort is completed, we'll be able to do more kinds of demilitarization, with greatly reduced hazardous waste and cost.



SYSTEM COMPONENTS: The demilitarization system we are using consists of a carbon dioxide blast cleaning system, ammunition tooling and an explosion-proof vacuum system. The CO_2 blast cleaning system components are the CO_2 pelletizer unit, an air compressor, an air dryer, and a liquid carbon dioxide storage tank. Specialized tooling mates the vacuum and the munition (a 5"/54 projectile for the test) to two kinds of explosive removal devices: a contour drill and the CO_2 blasting gun. The system uses a two-step process to remove the explosive from the projectile. The projectile is core-drilled with the contour drill first, then the CO_2 blasting system cleans out the rest of the explosive.



SYSTEM OPERATION: The projectile is placed in a lathe-type contour drill for processing. The drill uses a hollow shaft cutting bit that bores into the explosive filler as the projectile turns. The vacuum withdraws the powdered filler up the drill shaft as the bit cuts. A cam system causes the bit to follow the contour of the projectile cavity. Once the projectile has been core-drilled, the drill is retracted and positioned out of the way. A lining of explosive filler about 1/8 inch thick remains inside the projectile. The CO_2 blasting gun is mounted on the same positioning mechanism as the drill, and moves into position as the drill swings away. A brass bushing seals the connection between the blast gun and the vacuum. The CO_2 blast gun enters the projectile much like the drill bit does, but it doesn't require a cam system. The blasting action of the CO_2 pellets turns the explosive into powder, which is pulled out of the projectile by the vacuum. A special fitting allows the vacuum and the CO_2 blaster to work together, and a selector valve ensures the drill bit and the blast gun are not connected to the vacuum at the same time. When the projectile has been cleaned out, it is removed from the lathe chuck and the next one is put in its place. The first few projectiles processed on this system underwent extensive testing to determine the degree of cleanliness achieved, but the ultimate goal is a simple visual inspection to verify removal of the explosives.

HOW CO_2 BLASTING WORKS: The pelletizer creates CO_2 pellets by introducing liquid CO_2 into a low pressure chamber which causes the

liquid to turn into "snow". This CO_2 snow is extruded through a die to form the pellets. The pellets pass through an airlock where they enter the transport hose, and 35 psi pressurized air pushes them down the hose to the blasting gun. The blasting gun is supplied with high pressure blasting air through a separate hose. The blasting gun injects the CO_2 pellets into the high pressure airstream through a venturi at the opening of the nozzle. The nozzle accelerates the pellets up to supersonic speeds.

CONCEPT ORIGINATION: The concept for a CO_2 Blast/Vacuum system was formed by combining Air Force cleaning methods for bomb fuze wells and jet engines. The Air Force uses a blast/vacuum system to clean bomb fuze wells with glass bead blasting medium. Tinker Air Force Base uses a CO_2 blasting system to clean jet engine components. The Tinker system was featured in a "TechTIP" Technology Transfer Information Profile published by the Joint Technology Applications Office at Wright-Patterson Air Force Base.

We called the Process Engineering Section at Tinker AFB for information about CO_2 pellet blasting systems. Based on their advice, we contacted a company called Alpheus Cleaning Technologies, which is located in Rancho Cucamonga, California. Alpheus does sample testing for specific customer needs at either the customer's location or at their own facility in California. Since they agreed to do sample testing at their own location free of charge, we arranged a visit to try the concept with inert materials. The "proof of concept" test took place in the Alpheus test booth on November 8, 1990 and used an Alpheus CO_2 blasting machine.

TEST PREPARATIONS: Prior to visiting Alpheus, we prepared inert test samples and made a special test fixture to form a sealed system with a projectile, while mating the blast nozzle to the vacuum. We also coördinated with McAlester Army Ammunition Plant to give them an opportunity to participate in the test. The test articles were two 76mm projectiles press-loaded with a barium sulfate/magnesium sulfate mixture, two 76mm projectiles cast-loaded with "Filler E" (a mixture of wood rosin, stearic acid and dead-burned gypsum), and a 5-inch beaker (a plastic container that fits inside a 5-inch projectile) filled with an inert representative of Plastic Bonded Explosive (PBX). The McAlester Army Ammunition Plant representative brought two coffee cans filled with a slightly different kind of inert PBX.

TEST RESULTS: We tried the system on a press-loaded projectile first. We started working at 50 psi, which is the lowest blasting pressure possible, and found that very adequate for granulating the filler. The vacuum worked well, but the mating fixture severely limited the cleaning angles we could blast with. We started and stopped several times to allow inspection and tighten leaking seals on the fixture. Final cleaning had to be done without the vacuum fixture because of the limited cleaning angles. Total cleaning time was ten minutes. Next, we tried a projectile loaded with

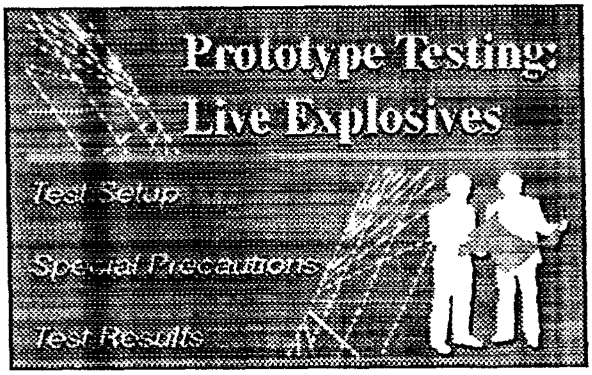
filler E. Again, we started at 50 psi blasting pressure. The filler E was much harder to grind up. Even after increasing the blasting pressure to 130 psi we only succeeded in creating a cone-shaped depression. We attempted to continue the test by removing the projectile from the fixture, but so much dust was created by blasting without the vacuum that we were forced to stop. However, cleaning was improved by the better angles achieved outside of the fixture. We put the second cast-loaded projectile in the fixture and concentrated the blast nozzle alongside the interior wall of the projectile. We were able to remove the filler E, but at a much slower rate than the pressed filler. The cavity paint was removed along with the filler.

Once we were finished with the projectiles we began testing the PBX samples. We anticipated that PBX would be very tough going for the CO_2 blasting system, so we chilled the beaker and one of the coffee cans in dry ice to make the samples more brittle. As we thought, the PBX samples were too resilient to break up very well with the CO_2 blaster. The best we found possible was one cubic inch of erosion in three minutes of blasting.

TEST SUMMARY: The test succeeded in showing that CO_2 blasting technology is definitely worth examination for use as a demilitarization method. The system we tested was able to clean out a pressed 76mm projectile in ten minutes at the lowest power setting. That would be faster than steamout (if you could steam out a pressed projectile), and slower than a drillout system. We were not satisfied with the test using filler E. The filler seemed much tougher than explosives such as Comp B or H-6 would be. After the CO_2 test was done we came across a test report on a water-jet system that also said filler E had different properties than actual explosives, and recommended adding 60 percent sand to replicate Comp B. We would like to try another test on filler E containing sand. We found the fact that the cavity paint was removed along with the filler an encouraging indicator of the system's cleaning power. If we can get the munitions that clean, we won't need to flash them (burn out explosives residue).

Our first design for a mating fixture proved that a vacuum could be used with a CO_2 blaster, but it also limited the cleaning effectiveness of the system. An improved mating fixture had to be developed to achieve better cleaning before we began tests on live explosives. Also, we had a tremendous static charge in our test fixture. We used a clear plastic tube so we could see the blasting nozzle, a feature we had to delete from our explosive tests for better grounding.

The CO_2 system did not show much promise for use with Plastic Bonded Explosives, or at least not on the cast variety. It may work better on press loaded types of PBX, perhaps we could try it on certain kinds of PBX sometime in the future. In the meantime, there are plenty of possibilities for developing demilitarization systems with TNT and RDX based explosives and that's where our testing program is most likely to be concentrated.



EQUIPMENT INSTALLATION: The CO_2 Blast/Vacuum system was installed in building 2504, an approved explosive operating building. The building has the necessary electrical power, compressed air, explosives vacuums and protective cells to adequately support this system. Equipment contractors installed the CO_2 tank and piping. The pelletizer contractor also provided training on how to operate the CO_2 system. CAAA engineers and technicians designed, installed and connected the rest of the system components.

SPECIAL PRECAUTIONS: Since the pelletizer unit is not explosion-proof, special care was taken to ensure the installation isolates the pelletizer from any possible exposure to explosive dusts and vapors. Only the blasting nozzle or "gun" is actually present in the cell where blasting takes place. The gun is explosion-proof and is connected to the pelletizer by a long set of hoses. The vacuum system is located in a position that isolates it from the operating cell and from the pelletizer unit. All vacuum components were inspected and refurbished before the tests began. Pneumatic operating controls were used, which are inherently explosion-proof. A control room was set up in a protective cell, and the system was monitored with a video camera.

SYSTEM TESTING: All equipment components of the system were thoroughly checked for proper operation before testing the system as a system. Initial testing to verify system operation and prove out specialized tooling was done entirely on inert loaded rounds. Inert testing was also used to allow Safety, Fire Department, Industrial Hygiene and Quality Assurance personnel to evaluate the system before attempting to use it on live rounds.

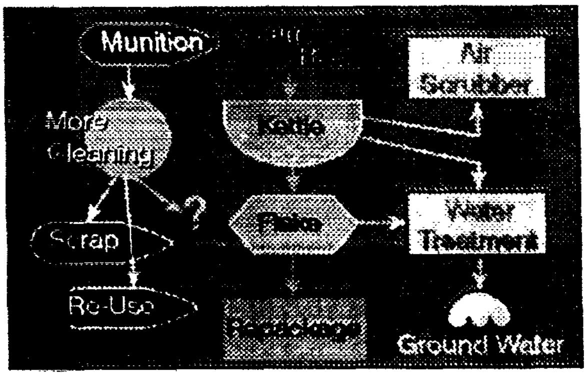
PRODUCTION TEST ITEMS: The CAAA testing program was designed to keep the process as simple and understandable as possible. We selected 5"/54 projectiles loaded with Explosive D as the lead test item. This ammunition has many attributes that made it especially suitable for our tests. It was available on station, we had tooling and equipment already designed for it, and empty bodies were available for use as inert test items. Explosive D is very insensitive to initiation from impact, and we have considerable experience demilitarizing Explosive D filled ammunition through the drill-out process. Using this ammunition allowed us to develop our tooling and procedures with very little risk of safety or engineering problems. The test period was limited to 16 rounds because of facility and funding constraints. Now that the test period is over, the test data is being used to develop criteria for certifying projectiles as "demilitarized"

and free of any requirement for further cleaning. The test data will also be used to develop and refine Standing Operating Procedures and test authorizations for trying the system on other projectiles and explosives. Once we have more experience with the system, we will probably seek to try it next on Composition A-3, which is likely to be the most sensitive explosive we will use this process on. If we are successful with Composition A-3, we are confident that we would also be successful with a wide range of less sensitive explosives.

OPERATOR TRAINING: The purchase contract for the CO_2 pelletizer included four days of demonstration and training in its use. Those technicians who were the first to operate this equipment attended this training. We selected experienced equipment operators who are already qualified to run explosives drilling and vacuum machinery. The first operators also participated in the initial testing on inert loaded rounds. This gave them as much training as possible prior to the first use of the system on live rounds.

TEST PRECAUTIONS: An inert testing period preceded the first use of the system on live rounds. This allowed us to verify the equipment was working the way we wanted it to. The inert testing phase was also used as much as possible to familiarize safety, fire department and EOD personnel with the process.

When the system had been checked, tested and approved through inert testing, testing on live rounds began. Rounds were depalletized in a room separate from the operating cell. Only one round at a time was permitted in the operating cell. Both the drill-out and the CO_2 blasting steps were done remotely and monitored with a video system. After the first round was done, the equipment was shut down and we waited five minutes before entering the cell to ensure no hazard remained. The round was removed from the equipment and visually inspected. Some visible residue remained near the bottom of the projectile cavity, so the equipment was adjusted and the test was started again on another projectile. Again, some residue remained near the bottom of the round. The nozzle was removed and lengthened, and the system was tried again on additional rounds. This time residue was left near the top of the round. A new hydraulic cylinder with a longer stroke was installed to increase the length of travel of the CO_2 nozzle. We tried it again on several more rounds, and were able to remove all but a small trace of the explosive near the top. We feel confident that with a little more experience with the system we can make the adjustments necessary to get the projectiles completely clean.



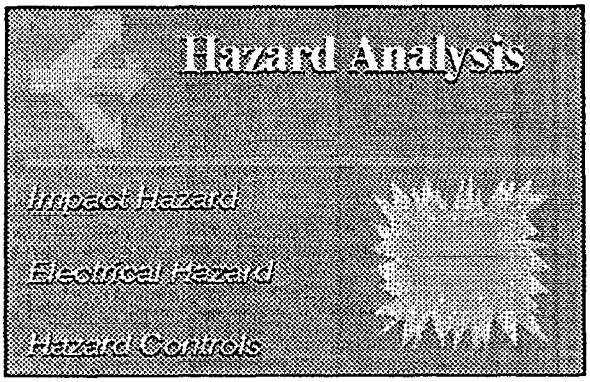
STEAMOUT SYSTEM CHARACTERISTICS: A Steamout Facility for demilitarization is much more complex than CO_2 Blast/Vacuum Demilitarization. The steamout facility at Crane has racks that hold the munitions at a downward angle while a steam probe is inserted into the case. As the explosive melts out, it drains through heated tracer lines to a collection kettle. The collection kettle keeps the explosive in a molten state until it is ready for further processing. Most of the water is drained off at this point and sent to the treatment plant. The kettle also requires a hood to capture the vapor rising from it, which uses a sophisticated air scrubber to remove the explosive contaminants.

The explosives collected in the kettle often require additional drying in a second kettle before it can be poured as pellets (much like bricks) or processed through a flaking machine. Once in a dry state, the explosive is packed in boxes.

The empty case is not clean enough to go directly from the steamout rack to the salvage yard. Cases being scrapped undergo thermal treatment, which means the remaining residue is burned out. If the cases are going to be reused, they have to cleaned out with a chemical solvent. Both of these alternatives generate additional waste streams.

LIMITATIONS OF STEAMOUT SYSTEMS: Steamout works well for cast explosives, such as TNT and TNT based compositions. However, it does not work for most press-loaded explosives, and does not work on many RDX based compositions. To be efficient, a steamout facility should operated 24 hours per day, because a lot of time can be lost in starting and stopping steamout production. And of course, a steamout plant requires an extensive boiler operation and a water treatment plant.

A CO_2 Blast/Vacuum Demilitarization system could be an excellent alternative to steamout. Procurement and installation costs are magnitudes less, and manpower requirements are much less too. A steamout facility is a permanent installation; a CO_2 system is relocatable, and can be moved from one place to another according to workload.



GENERAL INFORMATION: No one had ever tested or used a CO_2 Blast/Vacuum System as a demilitarization method before this test. Therefore, all potential hazards were evaluated and controlled prior to testing the system on explosives, and the system was tested on a relatively insensitive explosive.

Our hazard analysis concentrated on CO_2 blasting, as core drills and vacuums have been used with explosives for years, and the accompanying hazards and necessary safety precautions are well known. CO_2 blasting presents two hazards to explosive materials: shock from impact and static electricity. Friction, crushing, heat and chemical reaction hazards are not created by CO_2 blasting.

IMPACT HAZARD: CO_2 blasting accomplishes its work by bombarding the surface to be cleaned with dry ice pellets. These pellets hit the target surface at speeds from 700 to 1,500 feet per second, according to the equipment manufacturer. It is difficult to predict the hazard this impact might present to various kinds of explosives. Yes, we can calculate impact energy using pellet velocity, mass and surface area, but the energy threshold for reaction in a given explosive composition simply isn't available. The standard tests for impact sensitivity do not yield data that translate to usable numerical energy values. They are good for ranking the sensitivity of various compositions relative to each other, and for establishing the threshold for detonation, but little else. Ideally, we would like to know the threshold for reaction for any given explosive, and compare that with the energy produced by CO_2 pellet blasting. That simply isn't possible with the information available now. We <u>**do**</u> have information from fragment impact tests and high pressure water jet studies that suggested a reaction during CO_2 pellet blasting was highly unlikely, but we proceeded cautiously because of the lack of better data.

STATIC CHARGE HAZARD: CO_2 Blasting can build up a powerful static charge of electricity in ungrounded materials. We believe this is the single greatest hazard of CO_2 Blasting. The cold temperatures involved, and the extremely dry air we must use, are known to cause static charges unless effective controls are in place. During the initial test done in California, a charge of several thousand volts was measured in our tooling. However, the tooling was not grounded and a plastic component added to the problem. The production tooling is constructed entirely of conductive materials and is completely grounded. In addition, we have a built-in safety shut-off that shuts off the pelletizer if electrical continuity is

lost. The production equipment was also tested for static charges while in operation with inert materials. We found that a static charge was building on the projectile, so we added a grounded graphite brush that rubs on the rotating band, which solved the problem.

OTHER HAZARDS: Other possible hazards considered were dust escaping from the vacuum because of seals getting cold and shrinking; the vacuum not holding the pressure of CO_2 Blasting; and moisture condensing on the cold explosive when it is removed from the vacuum. None of these potential hazards materialized.

PROGRAM STATUS: Testing of the prototype CO_2 Blast/Vacuum Demilitarization system had to be terminated after running only 16 rounds, because the building had to be turned over for use with another project. The system will be removed and reinstalled in another location where a major production run can be done without conflicting with other workload. We are purchasing a new CO_2 storage tank and additional blasting equipment in anticipation of a renewed testing program in fiscal year 1993. (We used a leased storage tank for the test.) The report here represents program status as of 15 February, 1992.

CONCLUSION: Even though our CO_2 Blast/Vacuum initiative represents a tremendous advance in demilitarization capabilities, it does not solve all of the problems we face in this area. While it shows that technology transfusion is an extremely valuable tool, it also shows that we can't rely on the advance of technology to substitute for good, sound life cycle planning. We must do a better job of planning how to handle the disposal of ammunition and related products.

The requirement address disposal as a design element for new munitions has been in effect for several years now, but even so, viable alternatives to open burning and open detonation have not gotten the attention they deserve. A good way to get better, more cost effective disposal options would be to send the design to organizations that actually demilitarize munitions on a regular basis, and have them draw up the disposal plan. The DOD's most experienced "hands-on" experts, at Crane Army Ammunition Activity and McAlester Army Ammunition Plant, remain a hidden, untapped resource.

The CO2 Blast/Vacuum Demilitarization initiative shows they have the talent to develop innovative solutions to some of our toughest problems. Call (812) 854-1336, or DSN: 482-1336, for more information about government owned and operated demilitarization facilities.